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AN IMPROVED PROCEDURE FOR EVALUATION OF THE CHARACTERISTICS OF OCCUPATIONAL INJURY HAZARDS IN CERTAIN INDUSTRIAL OPERATIONS

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CHAPTER I

INTRODUCTION

The use of comprehensive, planned programs of activities for the control of occupational accidents has been a relatively recent development in industry in the United States. Such industry previous to the nineteenth century was of the handicraft variety using simple hand tools and manual or animal-powered machinery with extremely limited speeds and capacities. Only a few of the simpler varieties of materials were used, and these in small quantities. Seldom did the number of workers exceed two or three in any one plant or work location.

The early years of the nineteenth century marked the beginning of the use of mechanically-powered machinery with greatly-increased power and production capacity. This in turn, involved larger quantities of materials and greater numbers of employees in the plant. The occupational hazards of the handicraft era became more severe and were supplemented with additional types of hazards inherent in the beginnings of the "machine age."

The absence of reliable occupational-accident records for the early years of American industry makes it impossible to document (but it is generally accepted by students of industrial safety) that occupational accidents did occure in considerable numbers and that these numbers increased increased significantly during the eras mentioned above. Employers and the public persisted in the attitude that accidents to employees were inevitable by-products of production and that the employee accepted certain risks of accidents inherent in the job when he accepted employment. Even where employees regarded these concepts as unjust, they seldom could recover any losses resulting from occupational accidents because of the need for establishing negligence on the part of the employer, and the availability to the employer of certain common-law defenses.

Later in the nineteenth century, public reaction to the growing accident toll and the economic plight of the injured worker and his family, developed to the extent that widespread demands were made for corrective legislation. Some examples of the state sponsored legislation directed toward the safety problem during this early period were given by Heinrich (1).

Massachusetts

1867- Instituted factory inspection
1869- Established first state bureau of labor statistics
1877- Compelled guarding of dangerous moving machinery
1887- Passed an employer's liability law

Alabama

1885- Passed an employer's liability law

New Jersey

1911- Passed first state workmen's compensation law

The legislation sought to reduce hazards to factory workers by providing for safety inspections by State inspectors based on crude safety standards largely directed toward safeguarding moving machinery elements. Other laws attempted to provide partial relief to the injured employee for losses including medical treatment expenses and loss of income. The "employer liability" type of law proved ineffectual because of the legal difficulty of establishing employer negligence and because of the economic difficulty due to the expense and delay elements of a common-law legal action. The subsequent Workmen's Compensation Acts overcame these difficulties by eliminating questions of negligence and providing routine procedures for disposing of occupational injury claims promptly and usually without expense to the injured employee. Workmen's Compensation Acts were declared unconstitutional by the courts in several instances as they were held to violate the Fourteenth Amendment by "taking of a person's property without due process of law." However, in 1917, the Supreme Court of the United States declared that a State could enforce such laws under its power to protect the public health, safety, and welfare.

Industrial employers were gradually accepting more responsibility for the provision of safe working conditions and work methods beyond that compelled by law. Some were impressed by the temporary or permanent disability of needed skilled workers or the costly damage to machinery and tools, while others were motivated by humane reasons but in either case, the legal assignment of the responsibility and attendant costs of industrial accidents to the employer gave added impetus to accident-control measures by the employers.

Early accident-control efforts concentrated on the guarding of machinery particularly of the more massive, faster types. The size and speed of such machinery suggested a high degree of hazard with possibilities of serious or even fatal injuries. The accident records, after extensive machinery safeguarding, clearly demonstrated that machinery hazards and their control constituted only a segment of the industrial accident problem and that the scope of the control program needed to be expanded to include safe walkways, safe material storage and handling, proper tools, etc. Furthermore, the approach to the control of hazards had to be enlarged from that of exclusively engineering of machinery and machine accessories to encompass supervisory control of work practices and improved training of employees. The prevailing attitude of management toward safety measures during these early years regarded them as welfare activities and not as a means of attaining increased profit through accident reduction. In 1928, the Committee on Safety and Production of the American Engineering Council dispelled this opinion by stating "that there is a positive correlation between safety and efficiency of production and, in general, the safe factory is the efficient factory"(2). The integration of safety into the normal production and maintenance operations is now widely accepted and gains in production are being realized concurrently with gains in safety. Safety in the industrial operations does not hinder production but aids the worker in operating with improved efficiency. This increase in worker-effectiveness has prompted management to place more emphasis on the safety program and to encourage compliance with safe practices in industrial operations.

The control of a hazard requires at the outset an accurate identification or definition of the hazard to be controlled. This is not only a matter of definition of the problem to be solved, but permits some evaluation of the various hazards which seem to merit prompt attention and the development of the priorities as to which of the hazards shall receive earliest attention. The National Safety Council, American Standards Association, American Society of Safety Engineers, and others have published materials suggesting the hazards which could be expected in various industrial operations or situations as well as appropriate corrective measures. However, such listings merely provide clues to the detailed identification of the hazards and rarely will suffice in the complete hazard identification and the priorities involved. Some of the more serious hazards have been the subject of State and Federal legislation including mandatory compliance provisions.

The detailed identification of the hazards in the more complex industrial operations has been attempted in many different ways. The approach most widely used relies on frequency and severity rates based on the number of accidents, number of lost days, and the manhours of exposure in accordance with American Standards Association, Z16.1, American Standard Method of Recording and Measuring Work Injury Experience (3).

$$\text{Disabling Injury Frequency Rate} = \frac{\text{Number of Disabling Injuries} \times 1{,}000{,}000}{\text{Employee-hours of Exposure}}$$

$$\text{Disabling Injury Severity Rate} = \frac{\text{Total Days Charged} \times 1{,}000{,}000}{\text{Employee-hours of Exposure}}$$

These measures have been primarily used as "after the fact" evaluations of performance and appraisals of safety effectiveness. The industries, companies, plants, etc. with the highest rates are considered the most hazardous and assumed to have prime importance in any safety effort. The utilization of this method, in any specific industrial operation, is likely to be difficult because of the sizeable manhour exposure requirement for adequate statistical reliability. The number of accidents as well as the manhours' exposure is often relatively small for any reasonable time period and the results of these rates would tend to be unreliable. If the time period is lengthened to provide for a larger sample size, the validity of the measure is affected by time variations in production methods, physical facilities, labor force and even in the safety activities.

C. V. Culbertson (4) discussed a method of analyzing the frequency and severity rates in certain industrial operations. This study examined those portions of the operations of an industrial organization which contributed most to the over-all accident rates. It was determined that improvement in the most hazardous operations would contribute the greatest rate improvements to the organization. As with conventional methods, this procedure required the use of previous accident records for the specific operation with the accompanying problems of statistical reliability. A point, which was not considered, involved the evaluation of existing hazards in an operation which, as yet, had not caused an accident, yet appeared to possess appreciable hazard potential.

A different method of safety analysis of industrial operations was suggested by J. V. Grimaldi (5). Attempts were made to correlate various production cost data, such as salvage costs, material costs, labor costs, etc., with the safety experience of the organization. There was a slight indication that the salvage cost of an organization was negatively correlated with the accident experience but no further conclusions were drawn.

The identification of a safety hazard will not, in itself, eliminate the accidents due to that hazard in the industrial operation. An effective means must be developed to control the hazards present in any operation and to determine on which hazard to place the most emphasis.

The objective of this thesis is to test the hypothesis that an index can be developed to evaluate the extent of over-all hazard and the characteristics of that hazard in certain occupational activities. This index will provide a means of predicting future accident performance under existing conditions and a measure of the benefits to be expected from changed conditions which reduce the hazard. The hypothesis will be tested by correlation of the index to sets of historical data. The correlation thus developed with actual performance reflected in historical data, will then be studied to determine the validity of the model. The number of accidents occurring and the number of mandays lost due to accidents in the operation, will be used to measure the degree of hazard associated with the operation.

CHAPTER II

A SAFETY INDEX FOR EVALUATION OF HAZARD

Accident-control activities, of many varied types, have been increasingly used by almost every major segment of American industry down through the years. Even in the early era when motivation for such measures was largely based on a welfare attitude by management, and increasingly with wider recognition of the impact of accidents on production efficiency and the appearance of pertinent laws and regulations, the use of safety measures has steadily expanded.

The utilization of the frequency and severity rates was one of the typical control methods used during this period. Management tended to concentrate their safety efforts upon the operations with the highest rates in an attempt to improve the over-all accident experience. Numerous modifications of this rate computation were introduced in an effort to arrive at a more effective measure of safety performance, but these modified rates in large measure retained the limiting characteristics previously attributed to the ASA frequency and severity rates.

The identification of the "accident-prone" individual and his dismissal or transfer to alleviate relatively poor individual accident records was another method used to decrease the accident experience in an organization. Many companies, in the early 1950's, considered any person with more than one accident to be accident-prone. It was assumed that this factor, inherent in the individual, could not be corrected. Studies of the accident experience of the workers in an industrial organization indicated that the number of accidents per worker approached an "L-shaped" distribution with a few workers incurring a majority of the industrial accidents (6). The description of the accident-prone individual gradually gave way to the identification of "accident-repeaters." The identification of these workers was established on the basis of the number of accidents incurred in a specific operation and it was not assumed that this trait would be present in the same worker in another operation. As the identification of hazards in industry became more refined, the number of workers placed in the "accident-repeater" category diminished. W. B. Kerr (7) indicated that the accident-prone person did not incur a majority of the accidents but only one to fifteen percent of the occurrences. Thus this approach did not afford promise of any sizeable reduction in the over-all accident record.

Another control procedure for determining the distribution of injuries in an industrial operation was introduced by H. Gene Miller (8). This procedure evaluated the number of accidents per worker in an organization by use of a logarithmic scale. An example of this method involved an operation with 1000 employees and an average of 1.5 injuries per worker. It was shown that, in the entire organization, one worker could incur seven injuries and still be considered in the normal distribution. This observation supports the contention that persons who incur more accidents than their contemporaries may not necessarily be accident-prone.

The industrial accident statistics for the period 1926 to 1940 showed a reduction in the frequency rate from 33 to 13 for the industry as a whole (9). This reduction cannot be attributed to the specific control measures attempted since the hazards obvious to industrial personnel, were attacked and any measure could have operated effectively. The statistics for the years following 1940 have indicated a "leveling off" of the reduction in accident experience as indicated by a frequency of 14 in 1942, 13 in 1946, and 10 in 1951. This fact would suggest serious doubts as to whether the somewhat limited control measures of the immediate past years provide a sound basis for effective improvements in accident experience in future years.

There is always the risk of accidental injury in any activity in which humans are involved. This risk varies from one of minor injury to one of accidental death of the employee and from very frequent to infrequent occurrences. The most effective industrial safety program is concerned not with the question of eliminating all risks or hazards in an operation but of directing the efforts toward those hazards of greater accident potential and those in which a favorable economic balance is obtained between the cost of hazard control and the reduction in accident cost. Direction of the safety efforts to these areas will provide the most effective accident reduction procedure for any industrial operation. The problem in the most effective utilization of effort is one of identifying the most significant hazards in the operation. Heretofore, analysis of the industrial hazards has been on a basis of frequency and severity rates which were of questionable reliability. An industrial operation might not incur a disabling injury for an extended period while a comparable operation in another location might incur many injuries in a short period. The comparison of frequency and severity rates will show a great difference with as little as one accident in organizations of small numbers of manhours of exposure.

Identification of industrial hazards was often performed on a purely subjective basis. The combination of events leading up to the identification of the most hazardous operations has introduced a lack of definity and often an unacceptable degree of error in the hazard evaluation.

Efforts have been made to determine segments of the organization in which the best improvement could be made. Units such as plants, departments, and even individual persons have been identified as high-hazard units. Efforts have been made to decrease the hazards in these units of the organization with no basis other than the subjective decision of the safety specialist and management. The decision mechanisms, utilizing frequency and severity rates, in many cases proved inadequate for establishing the areas for greatest concentration of the safety effort due to the question of reliability of the measures and the inability to adequately estimate the amount of improvement to be expected. Little information is available on the correlation of a specific amount of safety effort to an associated improvement in accident potential.

To adequately combat any industrial accident problem, the causes of accidents must be investigated. This investigation should lead to an estimate of the accident potential of the industry and indications as to where effort should best be placed for the effective reduction of this accident potential. The procedure for evaluating the degree of hazard associated with a particular operation, to be developed in this thesis, will provide a more effective procedure for use in determining allocation of safety resources. Examination of the past data in a determination of the degree and nature of the hazard should provide a more reliable tool since accident experience, or lack of accidents, will not affect the results. Decisions, as to the degree of hazard, will be based on conditions existing in the operation at the time of the investigation and the data for the industry as a whole. The data pertaining to the entire industry will be assumed to be more reliable than that of the specific operation since the industry has a larger number of accidents and larger exposure. It is assumed that, over a sufficiently long period of time, the distribution of accidents in the specific operation will approach that of that operation throughout the industry. It is further assumed that the severity of accidents, due to a particular cause, in the specific operation will approach the severity of an accident, due to the same cause, in the industry. These assumptions appear to be logical since the industry, by definition, is composed of numerous similar organizations.

The characteristic hazards involved in any industrial operation can be most easily identified by examination of the causal factors of accidents in the industry. Causes of accidents may include unsafe acts on the part of employees unsafe mechanical or physical conditions, pre-existing physical limitations of employees, as well as other factors. The discussions in this thesis will be based upon the causal factors in the categories of "Unsafe Acts" and "Unsafe Conditions" since the main objective is to develop a method for identifying the degree of hazard involved in the operation and not with the condition of the operator. All accidents occurring in the industry are considered to be caused by some unsafe act or unsafe condition or a combination of these two. To effectively determine the causal factors in any operation, all the causal factors of accidents in the industry must be itemized. This will provide an insight into the major hazards of the particular industry. Once the causal factors of accidents are discovered, the statistics of the industry will be examined to determine what percentage of the accidents were caused by each factor. This percentage should provide a basis for estimating which causal factor is most likely to be present in an accident occurring in the specific operation. The severity of the accidents in each causal category will then be determined by calculating the average number of mandays lost per accident, in each causal category. The product of the severity and the percentage of accidents occurring in each category will be defined as the "hazard index" of that category. The hazard index should provide an estimate of the effect each specific causal category has on the average severity of an accident in the industry. This will be considered the degree of hazard associated with each causal category.

$$\text{Hazard Index} = \frac{\text{Mandays lost due to Accidents}}{\text{No. Accidents in Category}} \times \frac{\text{No. Accidents in Category}}{\text{Total Accidents in Industry}}.$$

On the basis of the assumptions concerning the relation of the distribution and the severity of accidents in the specific operation with that of industry, it follows that; if the operation had the same hazards associated with a particular causal factor, that were existing in the average industrial operation, the degree of hazard associated with that hazard in the operation would be the same as the degree of hazard associated with that causal factor in the average industrial operation. Common sense would indicate that all operations in an industrial field are not identical with respect to existing hazards. A rating must be developed to account for the differences between the specific operation and the average industrial operation. A rating system will be utilized to modify the hazard indices of the industry to provide an effective means of identifying the degree of hazard associated with the specific operation. The safety specialist will inspect the specific operation in question with respect to the causal factors developed from the industrial data. Each factor will be evaluated and assigned a rating to indicate the degree to which it is present in the specific operations as compared to the average industrial operation. A rating of 1.0 will be assigned when the degree of hazard is the same as that in the average operation and a rating of 0.0 will be assigned when the causal factor is not present in the specific operation. Ratings, varying from 1.0, will be used to indicate to what degree each causal factor exists in the operation.

The degree of hazard associated with each specific causal factor for the operation being considered will be the product of the hazard index and the rating of that causal factor in the specific operation. This will be defined as the "specific hazard index" and indicate the degree of hazard associated with each causal factor in the operation. This index will also indicate the amount each factor contributes toward the over-all accident potential of the operation and yield an estimate of the severity which might be expected, should an accident occur.

The evaluation of the operation will continue until all causal factors are considered. The specific hazard indices will then be added and the result will be defined as the "safety index" of the operation. The safety index will indicate the degree of hazard associated with the specific operation with respect to the average industrial operation. The highest specific hazard index will indicate the causal factor which contributes the greatest to the over-all index and the area which is likely to provide the most economical investment of safety resources. The operation with the highest safety index will also be considered the most hazardous and indicate the area of needed safety emphasis.

The following chapters will examine a sample industry and establish a safety index for specific operations within that industry. The safety index will then be compared with the past accident data for the operations to determine its effectiveness as a measurement of hazard.

CHAPTER III

APPLICATION OF THE PROPOSED SAFETY INDEX

The establishment of the safety index for a specific industrial operation requires an evaluation of the industry-wide accident experience. The industry to be considered, can be a company, division, manufacturing complex or other geographic or political division which encompasses similar operations. The size of the industry examined will determine the degree to which the operational hazards can be defined. An individual plant can be defined as the industry under observation, provided the number of accidents is sufficient to establish a valid distribution. The number of accidents required for a valid measure will depend upon the variability of the causes and other characteristics of the occurrences.

The type of industry being considered will determine the various causal factors present in the specific operation. These causal factors can be delineated by analysis of the accident data. The causes of accidents will vary somewhat with the specific industry. An over-all view of the various hazards present in an industry as well as the prevailing trends in accident control can be obtained from a listing of the specific causal factors.

The data on industrial accidents will then be examined to determine the severity of accidents to be expected for each causal factor. This severity will be based upon the average number of mandays lost due to accidental injury to the worker. The severity of accidents vary with the particular operation and cause of accident. It it assumed that all accidents occurring, due to each causal factor, will have an average severity which can be estimated and used in forecasting the expected severity of a future occurrence due to the same causal factor.

The industrial accident data will be further examined to determine what percentage of the accidents is attributable to each causal factor. This percentage will be based on the number of accidents occurring due to a specific cause, and the total number of accidents occurring in the industrial field for that causal category (unsafe act, unsafe condition, etc.).

The severity and percentage of accidents occurring for each causal factor will then be combined and the product will be defined as the hazard index for the cause. This hazard index will be used in determining the specific hazard indices and safety index of the operation.

The major industrial field evaluated in this study was the Air Force Logistics Command of the United States Air Force. This organization performs typical industrial operations such as, production, maintenance, and supply activities and accordingly provides a suitable application of the hazard index model. The Air Force accident reporting procedures vary slightly from normal civilian industrial procedures. Injuries which do not involve lost time to Air Force Personnel are not reported, while civilian accident statistics include the computation of the "medical cases," where the worker returned to the operation after treatment by some outside medical source. Civilian accident statistics include the actual cost of the medical treatment and disability payments under Workmen's Compensation Acts in the accident costs while

Air Force records are based on a standard cost figure of thirty dollars for military and fourteen dollars for civilian personnel for each day lost due to accidental injury. The differences in the costing method between the civilian operations and the military operations will not affect the results of this thesis since the severity will be based on the days lost to each operator due to injury rather than accident costs.

The data received from the United States Air Force for use in computing the safety index are categorized by activity of the person involved in the accident. Only those activities relating to the specific industrial-type operations will be considered in the determination of the degree of hazard involved in that operation. The activities considered will be: USAF aircraft-maintenance, repair, towing, including related activities; USAF supply including related activities; and USAF Air Installations (normal Air Base maintenance and construction). The other categories tabulated pertained to off-the-job activities such as; use of private motor vehicles, altercations and horseplay, sports activities, etc.

The causal factors, involved in the categories listed, were analyzed and separated into two major causal categories; unsafe acts and unsafe conditions. A code number was assigned for each causal factor (Tables 1 and 3) in accordance with the established procedure of the Air Force accident classification.

The data on the accidents in the Air Force Logistics Command were evaluated to determine the severity and percentage of accidents pertaining to each causal factor. The hazard indices were developed by the field (Tables 2 and 4). The hazard index, thus developed, provided the basis for examination of the specific operation to determine the associated degree of hazard. These hazard indices also provided an estimate of the most hazardous operations in the Command and an estimate of the amount an accident in the specific causal factor affects the average severity of an accident in the field.

The application of the hazard indices to a specific operations will be described in the following chapter. These indices, along with the rating of the specific cause, should provide an accurate estimate of the degree of hazard and the characteristics of that hazard, associated with the specific industrial operation.

Table 1

Coding for Specific Causal Factors of Unsafe Conditions

Code	Unsafe Mechanical or Physical Condition
01	Defective aircraft
02	Defective motor vehicle, brakes
10	Defective motor vehicle, motor, clutch, transmission
19	Defective motor vehicle, other
20	Defective special purpose vehicle
22	Extreme weather conditions (tornado, hurricane, windstorm, extreme heat, extreme cold, etc.)
23	Glare from sun, other intense light sources
25	Slippery surface from spillage or leakage
26	Slippery surface due to ice, snow, sleet, rain, etc.
27	Rough, defective, hazardous surface
28	Smooth, highly polished surface
29	Hazardous arrangement or procedure (unsafely stored or piled tools, materials, etc.; congestion of working spaces; inadequate aisle space, exits, etc.; unsafe planning and/or layout of traffic or process operations)
30	Hazardous location (unprotected, unmarked floor openings, street intersections, excavations, etc.)
31	Hazardous dress or apparel (does not pertain to personal protective equipment)
32	Limited visibility due to fog, rain, snow, sleet, dust storm, etc.
33	Improper or inadequate illumination
34	Improperly designed machinery equipment, etc.
35	Improperly guarded, unguarded machinery equipment, etc.
36	Inadequate ventilation
37	Mechanical failure of machinery, equipment, etc.
38	Personal protective equipment not available
39	Personal protective equipment defective or sub-standard
40	Unvented vessels, containers, tanks, etc.
41	Work space limitation, small, cramped due to nature of work
42	Excessive noise due to aircraft run-up, aircraft take-off machine operation, vehicle operation, etc.
55	Lack of, or unavailability of, prescribed or specially designed machinery, equipment, etc.
97	Defective machinery, equipment, other.
98	Unsafe mechanical or physical condition, other
99	No unsafe mechanical or physical condition

Table 2

Unsafe Conditions with Relation to Severity,

Percentage Occurrence, and Hazard Index

Cause Code	Severity	%A	Hazard Index
01	.83	.005	.0042
02	-----	.002	------
10	-----	.001	------
19	6.33	.002	.0127
20	3.78	.030	.1134
22	5.00	.019	.0950
23	-----	.001	------
25	18.84	.030	.5652
26	14.61	.074	1.0812
27	9.08	.021	.1907
28	8.50	.001	.0085
29	9.65	.063	.6080
30	5.56	.007	.0389
31	2.00	.002	.0040
32	-----	.004	------
33	3.00	.017	.0510
34	11.75	.010	.1175
35	12.33	.019	.2343
36	-----	.001	------
37	3.60	.010	.0360
38	15.00	.002	.0300
39	10.50	.002	.0210
40	90.00	.001	.0900
41	6.00	.007	.0420
42	5.83	.005	.0292
55	14.75	.019	.2803
97	5.49	.061	.3349
98	9.10	.033	.3003
99	7.30	.559	4.0807

Table 3

Coding for Specific Causal Factors of Unsafe Acts

Code	Unsafe Act of Person Reported
02	Disregard of traffic controls
04	Driving on the wrong side of the road
20	Allowing personnel to ride on vehicle
21	Backing vehicle without checking clearance or traffic
22	Driving vehicle forward without checking clearance or traffic
23	Excessive speed for conditions
24	Failure to note, correct or report obvious defect of vehicle
25	Failure to properly secure or check hitches of trailers, towbars, etc.
26	Failure to secure load, seat personnel, close doors, or secure tail gate of special purpose vehicle
27	Misues or improper use of vehicle
28	Overloading, overstress of vehicle
29	Unsafe act, special purpose vehicle, etc.
31	Extending body or part of body into hazardous location
32	Getting on or off moving equipment or vehicles
33	Jumping rather than ascending, decending, crossing by other means
34	Lifting, moving, carrying while in improper position
36	Riding in unsafe position
37	Running, walking too fast for conditions
38	Sitting, standing or moving in awkward or hazardous manner
39	Standing too close to equipment, machine, or vehicle in operation
42	Utilizing make shifts instead of proper supports
46	Arranging or placing objects or materials unsafely
47	Holding or gripping objects or materials in securely or improperly
49	Inadequate or no help in lifting, moving carrying objects or materials
51	Introducing flame, heat, or other spark producing tools or equipment into hazardous area
52	Lifting, moving, carrying by hand, when use of mechanical device is standard operating procedure and available
53	Stacking material too high or improperly
56	Improper adjustment of tool or equipment
57	Improper use of tool or equipment (using heavy file as hammer)

Table 3 (continued)

Coding for Specific Causal Factors of Unsafe Acts

Code	Unsafe Act of Person Reported
58	Unsafe use of tools or equipment, or otherwise using tools or equipment unsafely
60	Use of defective tools, equipment or material
61	Use of hands instead of proper tools or equipment
63	Inadvertent or incorrect utilization of control or operating mechanism or device
66	Cleaning, oiling, adjusting, repairing machines or equipment while in operation
67	Feeding or supplying too rapidly
70	Failure to wear proper attire
71	Failure to wear safety spectacles, goggles, gloves, masks, aprons, shoes, leggings, sports protective equipment, etc.
72	Wearing finger ring
73	Wearing improper or defective footwear
74	Wearing jewelry, chains, etc.
79	Extended horseplay, practical joking
83	Failure to (or adequately) block, shore or use cribbing
84	Failure to check, inspect, signal or warn
85	Failure to comply with tech orders, regulations, safety rules, etc.
87	Failure to lock or secure vehicle, equipment, or machinery
88	Failure to notice obvious hazard
90	Failure to recognize or compensate for own physical limitation or lack of ability
91	Failure to remove or correct obvious hazard
93	Failure to properly execute a sports action or maneuver
94	Failure to use available safety device
98	Miscellaneous unsafe act
99	No unsafe act of person reported

Table 4

Unsafe Acts with Relation to Severity,

Percentage of Occurrence, and Hazard Index

Cause Code	Severity	%A	Hazard Index
02	1.00	.001	.0010
04	5.00	.001	.0050
20	3.50	.002	.0070
21	----	.022	-----
22	3.21	.047	.1509
23	.33	.015	.0050
24	6.07	.013	.0789
25	----	.005	-----
26	----	.008	-----
27	1.40	.008	.0112
29	2.18	.041	.0894
31	13.99	.062	.8674
32	5.00	.001	.0050
33	4.20	.013	.0546
34	6.15	.044	.2706
36	45.00	.003	.1350
37	14.64	.018	.2635
38	8.13	.100	.8130
39	11.17	.005	.0559
42	19.92	.011	.2191
47	6.05	.016	.0968
49	7.22	.041	.2960
51	9.50	.002	.0190
52	10.73	.009	.0966
53	3.00	.001	.0030
56	6.00	.006	.0360
57	14.71	.018	.2648
58	15.07	.012	.1808
60	8.00	.008	.0640
61	5.29	.006	.0317
63	3.06	.015	.0459
66	7.92	.011	.0871
67	90.00	.001	.0900
70	6.75	.003	.0203
71	7.17	.025	.1793

Table 4 (continued)

Unsafe Acts with Relation to Severity,

Percentage of Occurrence, and Hazard Index

Cause Code	Severity	%A	Hazard Index
72	14.21	.012	.1705
73	3.50	.007	.0245
74	16.00	.001	.0160
79	7.00	.001	.0070
83	-----	.001	-----
84	7.14	.023	.1642
85	11.29	.074	.8355
87	4.93	.024	.1183
88	10.20	.114	1.1628
90	4.67	.008	.0374
91	17.50	.028	.4900
93	4.00	.001	.0040
94	18.08	.010	.1808
98	3.50	.002	.0070
99	5.64	.112	.6317

CHAPTER IV

TESTING OF PROPOSED SAFETY INDEX IN SPECIFIC INDUSTRIAL OPERATIONS OF THE UNITED STATES AIR FORCE

The estimation of the degree of hazard associated with specific industrial operations utilizes the hazard indices developed for industry-wide data and an examination of the specific operations. The specific industrial operation may be of any size or involve any production, maintenance, or supply facilities. The safety specialist investigates the operation and rates the degree of hazard in each causal category. This rating is then applied to the hazard indices of the industrial field to determine the specific hazard index for each causal factor. The specific hazard index will indicate the degree of hazard associated with the specific cause and estimate the effect that the cause has on the over-all accident experience of the operation. The summation of the specific hazard indices in an individual operation will yield the safety index of that operation. This safety index will be compared with the index developed for other operations to identify the more hazardous activities. The area with the highest safety index will be the most hazardous and the area with the lowest index will be the least hazzrdous. Figure 1 indicates the development of the safety index from the causal factors of accidents in the industrial field.

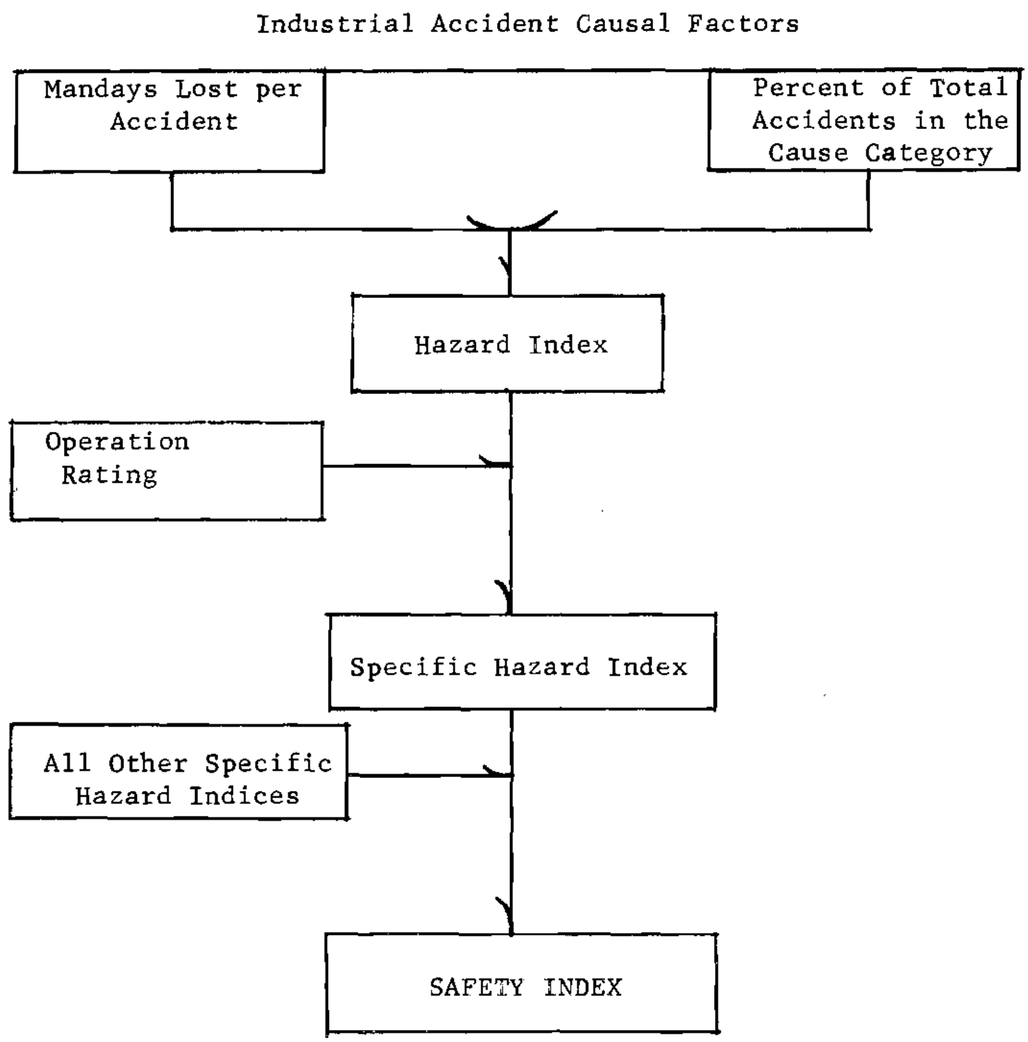

Figure 1

Development of the Safety Index

The specific operations considered in this thesis were examined at Robins Air Force Base, Georgia. This division of the Air Force Logistics Command was chosen because it was immediately available and the accident statistics required were present in the Safety Office. The operations, which were to be rated, were selected from among four different areas of operation in an attempt to obtain an estimate of the applicability of the index to diversified operations.

The first operation studied was the Air Terminal Division. This operation is similar to that of a material-handling section of a manufacturing plant or freight terminal. The major responsibility of this operation is the processing for shipment and receipt of all air transported shipments. This operation has an all weather, twenty-four hour, handling responsibility.

The Sheet Metal Shop of the Maintenance and Repair Branch was the next operation studied. This operation rebuilds and repairs aircraft control surfaces and external coverings. The operations include power presses, brakes, and similar metal working machines. The portion of the operation evaluated was the control surface build-up and the pre-assembly operations on raw materials.

The Hydraulics Shop was the third operation studied. This activity involves the reworking and testing of all hydraulic components of the aircraft system. Individual work stations are set up for the reworking operation and a testing laboratory evaluates the finished product. The hazard of high pressure, air and hydraulic, appeared to present significant accident causal factor to the operation. The reworking section involves the normal production line hazards with small hand tools and manual assembly.

The Assembly and Blade Repair section of the Propeller Shop was the final operation considered. This section performs the rebuilding of propeller blades and associated control mechanisms. Radiation, use of small hand tools, and toxic chemicals were a few of the hazards associated with this operation.

Examination of these four areas was made, by the author, on a personal visit to Robins Air Force Base. The individual causal factors in each operation were rated and evaluated by the procedure established in this thesis. The safety index for each operation was developed to denote the associated degree of hazard. The establishment of this index was accomplished by the summation of the specific hazard indices for each operation.

Past accident data for the four operations was then studied. This data included the accident records for 1959, 1960, and 1961 calendar years. It was assumed that the data for this period would provide an adequate measure of the effectiveness of the safety index. Data for earlier periods was not regarded as accurate. The total number of accidents for the three year period in each operation were tabulated and listed with the number of mandays lost and the number of personnel involved in the operation (see Table 5).

The safety index, for each operation, was then tested by correlation with the past data of the operations in question. Due to the small number of operations studied, a linear correlation was assumed, if one existed. The following formula was used to compute the coefficient of correlation between the safety index and the number of accidents per operation.

$$r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x}) \sum_{i=1}^{n} (y_i - \bar{y})}} .$$

Where: x_i = safety index of the operation for

$i = 1$ to n.

y_i = number of accidents for the operation

for $i = 1$ to n.

The coefficient of correlation between the safety index and the number of accidents per operation was .908. This would indicate that the number of accidents per operation was positively correlated with the safety index of the operation. The safety index, however, is not dependent upon the size of the operation but the number of accidents will depend upon the exposure of the employees. The coefficient of correlation was then calculated between the safety index and the number of accidents per 100 employees in the operation. It was assumed that the number of accidents per 100 employees would not be dependent upon the size of the operation. The coefficient of correlation between the safety index and the number of accidents per 100 employees was .86. This figure was tested for significance and it was determined that the coefficient of correlation was significantly different from zero at the 85 per cent level of significance.

The analysis of the testing procedure indicated that the safety index was positively correlated with the number of accidents per 100 employees and the data concerning the severity of the accidents in each operation did not appear to be correlated for the number of operations studied.

Table 5

Comparison of Safety Index and

Past Performance

Operation	Employees	Past Performance		Safety Index
		No. of Acc.	Severity	
Air Term.	91	0	0	12.8660
Hydraulics	183	1	10	14.8311
Sheet Mtl.	237	3	30	16.1315
Blade Rpr.	176	5	21	16.4326

CHAPTER V

CONCLUSIONS

The objective of this thesis was to test the hypothesis that an index could be developed to evaluate the extent of over-all hazard and the characteristics of the hazard in certain occupational activities. It was assumed that this index would indicate the degree of hazard in an operation as characterized by the number and severity of accidents occurring in the operation.

The causal factors of accidents in the Air Force Logistics Command of the United States Air Force were studied and a hazard index was developed which would indicate the degree of hazard associated with each cause. Four specific operations were examined at Robins Air Force Base, Georgia and a safety index was computed by combining the hazard indices and rating for each causal factor present in the operation. The results of this investigation were then tested by linear correlation with past accident data for the operations. It was shown that the safety index was slightly correlated with the number of accidents per 100 employees per operation at the 85 per cent level of significance. No correlations were obtained between the safety index and the degree of hazard as indicated by the severity of accidents occurring in the operations. There were indications that the safety index could provide an estimate of the degree of hazard associated with specific industrial operations. Data from more operations in this industrial field is required to increase the reliability of the correlation and to determine if the assumption of a linear correlation was valid.

This procedure indicated that an effective tool has been developed to determine the degree of hazard and the characteristics of that hazard for the Air Force Logistics Command. More data is required to verify the results obtained in this thesis. It is recommended that this procedure be tested further, using data from other industrial fields, to indicate the effectiveness of the index as an adequate tool for use generally in industrial safety applications.

APPENDIX A

CHECKLIST FOR USE IN DEVELOPING THE SAFETY INDEX FOR AIR FORCE LOGISTICS COMMAND OPERATIONS

Use of Checklist

The checklist, listed in this section, will be used for the evaluation of all Air Force Logistics Command operations. This evaluation will involve the rating of each individual operation as to the presence of each of the categories of causal factors as compared with the normal AFLC operation. The qualified safety person, rating the operation, should consider each category and establish a percentage rating of the category's effect on the accident experience as compared with the effect of the same category on a typical operation. The rating developed for each category should be multiplied by the industrial hazard index for the particular category to arrive at the specific hazard index. The specific hazard indices will be summed and the result will be the safety index for the specific operation.

SAFETY INDEX CHECKLIST

Causal Category Code	Hazard Index	Rating (%)	Spec. Hazard Index
Unsafe Conditions			
01	.0042		
02	-----		
10	-----		
19	.0127		
20	.1134		
22	.0950		
23	-----		
25	.5652		
26	1.0812		
27	.1907		
28	.0085		
29	.6080		
30	.0389		
31	.0040		
32	-----		
33	.0510		
34	.1175		
35	.2343		
36	-----		
37	.0360		
38	.0300		
39	.0210		
40	.0900		
41	.0420		
42	.0292		
55	.2803		
97	.3349		
98	.3003		
99	4.0807		
Unsafe Acts			
02	.0010		
04	.0050		
20	.0070		
21	-----		
22	.1509		
23	.0050		
24	.0789		
25	-----		

SAFETY INDEX CHECKLIST (continued)

Causal Category Code	Hazard Index	Rating (%)	Spec. Hazard Index
Unsafe Acts (cont.)			
26	-----		
27	.0112		
28	-----		
29	.0894		
31	.8674		
32	.0050		
33	.0546		
34	.2706		
36	.1350		
37	.2635		
38	.8130		
39	.0559		
42	.2191		
46	.0968		
47	.3641		
49	.2960		
51	.0190		
52	.0966		
53	.0030		
56	.0360		
57	.2648		
58	.1808		
61	.0317		
63	.0459		
66	.0871		
67	.0900		
70	.0203		
71	.1793		
72	.1705		
73	.0245		
74	.0160		
79	.0070		
83	-----		
84	.1642		
85	.8355		
87	.1183		
88	1.1628		
90	.0374		
91	.4900		
93	.0040		

SAFETY INDEX CHECKLIST (continued)

Causal Category Code	Hazard Index	Rating (%)	Spec. Hazard Index
Unsafe Acts (cont.)			
94	.1808		
98	.0070		
99	.6317		
		Total Safety Index	

APPENDIX B

CHECKLISTS FOR RATED ORGANIZATIONS

The following pages contain the checklists which were completed on the four operations at Robins Air Force Base, Georgia. The hazard index applying to each causal category may be obtained from Tables 2 and 4.

SAFETY INDEX CHECKLIST
(Air Terminal)

Cause Code	Rating	Specific Hazard Index
Unsafe Cond.		
01	1.0	.0042
20	1.3	.1474
22	1.5	.1515
25	1.3	.7348
26	.7	.7568
29	1.3	.7904
30	.8	.0311
31	1.0	.0040
33	1.5	.0765
35	1.0	.2343
37	1.0	.0360
38	.8	.0240
42	1.0	.0292
97	1.0	.3349
98	1.0	.3003
99	1.0	4.0807
		7.7361

Cause Code	Rating	Specific Hazard Index
Unsafe Act		
20	1.0	.0070
22	1.2	.1811
23	1.3	.0065
24	1.0	.0789
27	1.0	.0112
31	.5	.4337
32	1.2	.0060
33	1.0	.0546
34	1.5	.4059
36	1.3	.1755
37	.3	.0791
39	1.0	.0559
46	1.0	.0968
47	1.5	.5462
49	1.5	.4440
52	1.2	.1159
53	1.0	.0030
61	.7	.0222
63	.5	.0230
70	.5	.0102
71	.2	.0359
72	.8	.1364
84	.7	.1149
85	1.0	.8355
88	.5	.5814
90	1.0	.0374
99	1.0	.6317
		5.1299

SAFETY INDEX = 7.7361 + 5.1299 = 12.8660

SAFETY INDEX CHECKLIST
(Sheet Metal)

Cause Code	Rating	Specific Hazard Index	Cause Code	Rating	Specific Hazard Index
Unsafe Cond.			Unsafe Act		
25	.3	.1696	31	1.8	1.5613
27	.4	.0936	33	1.0	.0546
29	1.0	.6080	34	1.0	.2706
30	1.3	.0506	37	1.0	.2635
33	.8	.0408	38	.8	.6504
34	1.5	.1763	39	1.5	.0839
35	1.5	.3515	42	.5	.1096
37	1.0	.3060	46	.3	.0290
38	.4	.0120	47	1.3	.4733
42	1.3	.0300	49	1.5	.4440
97	1.0	.3349	52	1.2	.1159
98	1.0	.3003	56	1.3	.0468
99	1.0	4.0807	57	.8	.2118
		6.2843	58	1.3	.2350
			60	.8	.0512
			61	1.5	.0476
			63	1.5	.1307
			67	.3	.0270
			70	.8	.0162
			71	.8	.1434
			72	.2	.0341
			84	1.3	.2135
			85	1.5	1.2533
			87	1.3	.1538
			88	1.5	1.7442
			91	1.5	.7350
			94	.5	.0904
			98	1.0	.0070
			99	1.0	.6317
					9.8472

SAFETY INDEX = 6.2843 + 9.8472 = 16.1315

SAFETY INDEX CHECKLIST
(Hydraulic Shop)

Cause Code	Rating	Specific Hazard Index
Unsafe Cond.		
25	1.3	.7348
27	.5	.0954
28	.2	.0017
29	1.3	.7904
33	.5	.0255
34	1.3	.1528
35	1.5	.3515
37	1.0	.0360
38	1.0	.0300
39	.8	.0168
40	2.5	.2250
41	1.3	.0546
42	1.3	.0380
97	1.0	.3349
98	1.0	.3003
99	1.0	4.0807
		7.2684

Cause Code	Rating	Specific Hazard Index
Unsafe Act		
31	1.5	1.3011
34	.8	.2165
37	1.3	.3462
38	1.3	1.0569
39	.8	.0447
42	1.0	.2191
46	1.0	.0968
47	1.0	.3641
49	1.0	.2960
51	1.0	.0190
52	1.0	.0966
56	1.0	.0360
57	.8	.2118
58	1.0	.1808
60	1.0	.0640
61	1.3	.0412
63	1.3	.0597
66	1.0	.0871
67	.5	.0450
71	1.3	.2331
72	.8	.1364
73	.5	.0123
74	.8	.0128
84	1.3	.2135
85	1.3	1.0862
87	1.5	.1775
88	.8	.9302
91	.7	.3430
98	1.0	.0070
99	1.0	.6317
		7.5627

SAFETY INDEX = 7.2684 + 7.5627 + 14.8311

SAFETY INDEX CHECKLIST
(Assessory & Blade Repair)

Cause Code	Rating	Specific Hazard Index	Cause Code	Rating	Specific Hazard Index
Unsafe Cond.			Unsafe Act		
20	.5	.0567	21	1.5	1.3011
25	1.3	.7348	33	.8	.0437
27	.3	.0572	34	1.5	.4059
28	.4	.0034	37	1.3	.3426
29	.8	.4864	39	1.3	.0727
30	1.8	.0700	42	1.3	.2848
31	1.0	.0040	46	1.0	.0968
33	1.0	.0510	38	1.0	.8310
34	1.5	.1763	47	1.3	.4735
35	1.0	.2343	49	1.5	.4440
37	1.0	.0360	51	1.3	.0247
38	.8	.0240	52	1.8	.1739
41	.8	.0336	56	1.0	.0360
42	1.0	.0292	57	1.3	.3442
55	1.5	.4205	58	1.3	.2350
97	1.0	.3349	60	1.3	.0832
98	1.5	.4505	61	1.3	.0412
99	1.0	4.0807	63	.4	.0184
		7.2835	66	.3	.0261
			70	.8	.0162
			71	1.3	.2331
			84	1.0	.1642
			85	1.0	.8355
			87	1.3	.1538
			88	1.3	1.5116
			91	.5	.2450
			94	.5	.0904
			98	1.0	.0070
			99	1.0	.6317
					9.1491

SAFETY INDEX = 7.2835 + 9.1491 = 16.4326

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